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# Analog years: Connecting climate science and agricultural tradition to better manage landscapes of the future

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ABSTRACT

Climate scientists rely on observed historical weather and climate data to inform current and future climate model projections. Similarly, agricultural producers use historical events—recent past experiences and historical narratives—to construct local knowledge to assess, quantify, and manage current and future risks. These historical data, events, and experiences become reference points or analogs when compared to a current phenomenon that exhibits similar characteristics specific to past conditions. In this paper we utilize a lens of agricultural traditions and past experiences to posit a temporal reference framework. In-person interviews with 159 Midwest farmers illustrate how the past influences farmers' perceptions of current and future risks and is used to integrate scientific climate information to inform decision-making. Qualitative analysis provides support for the temporal reference framework, but more empirical testing is needed to further validate the model.


## 1. Introduction

Decisions about agricultural management, such as soil tillage, result in outcomes that are compounded across time (Lal, 2004; Grandy et al., 2006; Mathew et al., 2012). These actions can make the difference between retaining soil organic carbon to assure long-term productivity or losing soil to erosion and compromising agroecosystem services for short-term gain. Humans use feedback from past experiences and reference these benchmark events as “analogs” to inform current decision-making. Values and local knowledge systems are developed through a dynamic and continual process of social learning and act as a filter through which individuals perceive and act to address climate risk (Adger et al., 2008; Wolf et al., 2012). Social knowledge activates the experiential system which emphasizes relational timescales of past experience, while scientific knowledge activates the analytical system of linear or sequential timescales (Raedeke and Rikoon, 1997; Hautala and Jauhiainen, 2014; Slovic et al., 2004). Understanding how farmers perceive and use time as a reference to inform management decisions under increasingly variable climate and extreme weather events can help agricultural advisors and educators encourage effective adaptive strategies to reduce climate risks to agriculture.

Human perspective of time is an important predictor variable in environmental decision-making and normative behavior (Milfont and Gouveia, 2006; Milfront et al., 2012; Coser and Coser, 1990). Dietz et al. (2007:192) conceptualize temporal orientation as a causal variable and “stable, trait-like characteristic” in predicting support for climate change-related behaviors. Temporal references are shown to “have a determinant influence over what individuals and groups perceive in the world, how they construct their range of possible actions, and how they realize their existence” (Taddei, 2011:260). In agriculture,

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farmer perceptions of the risks that extreme weather and climate variability present influence decisions and actions which in turn can impact soil-plant-atmosphere interactions. The effects of tillage and other soil management practices are often not visible within an annual time cycle but accrue in time horizons of decades or generations. Similarly, the concept of climate, or the distribution of daily weather over time, is difficult for many people to interpret at human timescales and can influence understanding of climate change and subsequent decision-making (Dahlstrom, 2014; Milfront and Demarque, 2015; Weber, 2006; Weber and Stern, 2011; NASA, 2005). Thus, farmer perceptions of time play an important role in assessment of current options and the kind of strategies needed to adapt to changing weather and climatic conditions.

Jackson et al. (2010) identify time as one of three types of scale used to evaluate and plan for sustainability of agriculture into the future. They propose a hybrid sustainability concept that combines sustainability—the meeting of current needs without compromising the needs of future generations—with the flexibility of adaptive capacity. The temporal framework presented by Jackson et al. (2010) is intended to represent planning for future uncertainty and risk and the rapid pace of human-induced environmental change. Along the time axis, efficiency dominates the here-and-now while longer term planning is focused on adaptation to future risk and continuation of agroecosystem functioning. They propose that farmer management decisions at many scales are primarily driven by private benefits "now" that generate economic returns. What this model overlooks is the past and how past experiences and historical narratives influence decisions in the "now" and can change perceptions of adaptive management alternatives. While much of our knowledge about sustainable behavior is future-oriented (Jackson et al., 2010), this orientation fails to recognize the contribution of past experiences and historical narratives that signal reactional or responsive adaptation to address future climate risks (Darnhofer et al., 2010; Raedeke and Rikoon, 1997; Riley, 2008). As time progresses, current decisions and experiences become the benchmark or analog to which future decisions are referenced and weighted.

This research addresses the gap in how time is theorized as it relates to agricultural decisions within the coupled human-agroecosystem at the farm-scale level. Time is conceptualized as a key variable that guides farmer decision-making and normative behaviors. A decision timescale framework is synthesized and built from several literatures, and then truncated to amplify the recent and historical past as feedback that guides farmer decision-making in the here-and-now. A temporal reference model is then developed to conceptualize the iterative and dynamic nature of social learning that occurs as recent past experiences and outcomes as well as intergenerational narratives are brought forward to inform a current decision point. Interview data gathered in 2013 from 159 Midwestern corn farmers are used to illustrate, refine, and provide empirical evidence for the model in preparation for future model testing. Following a presentation of results from in-person interviews, a discussion of model application elaborates how the past influences current farmer decisions. We conclude by suggesting the concept of temporal reference allows communication techniques and frames which provide analogous or historically-referenced and socially relevant information. By talking about agricultural risk trends over a timescale that encompasses the past as well as the future, scientists may more effectively convey useful and useable agricultural climate risk information.

### 1.1. Temporal reference in climate and agriculture

Agricultural production in the United States Corn Belt is increasingly vulnerable to risks from extreme weather events and changing climate conditions (Walthall et al., 2012; Hatfield et al., 2014; Challinor et al., 2014). Adapting farm practices to reduce the threats of future climate risks requires adjustments in current grain cropping management systems (Hatfield et al., 2011; Howden et al., 2007; Delgado et al., 2011). Climate science can provide decision support to help agricultural producers adapt to environmental risks from extreme weather events and climate variability (Takle et al., 2014; Wilke and Morton, 2015a). However, farmers and other agricultural decisions makers have been reluctant to accept and utilize knowledge of climate science to inform current and future land management decisions. This barrier to effective climate risk communication is exacerbated because decision-makers may not perceive scientific climate information and data as usable to inform decisions (Lemos and Rood, 2010; Briley et al., 2015). As Palmer (2012:5) notes, "Facts, figures, and future projections on the biophysical impacts of climate change or energy production have had far less of an effect" than many scientists had hoped. Thus, it is important to identify factors that may inhibit or obscure the transfer of knowledge from researchers to decision-makers in the context of climate and agriculture. These factors may involve not only one-way knowledge transfer, but also multi-directional exchanges, and the co-development of knowledge between scientists and information users (Meadow et al., 2015; Dilling and Lemos, 2011; Lemos and Morehouse, 2005).

Several lines of research suggest the importance of temporal reference and the role of past experiences with weather and climate. Ingram et al. (2013:267) study the adoption of sustainable agricultural management and observe that "incorporating a temporal dimension into the wider question of farmers' participation in agri-environment schemes can help to improve understanding of farmers' behavior". Adger et al. (2008:346) explore social limits to the adaptation of climate change and conclude that "historical and current adaptation is and continues to be informed by perceptions and local knowledge based on previous experience of weather and climate". Further, they suggest that "it is unclear how insights from the past could serve us in the face of future climate changes". Haigh et al. (2015:29) similarly conclude the need for "further investment in the use of historical climate information to quantify potential climate risks for agricultural decision makers". This research strongly suggests that temporal dimensions, particularly historical narratives and past experiences, play a prominent role in reception of climate risk information and agricultural decision-making.

While there have been numerous studies on adoption of science-based farm management practices (e.g. Baumgart-Getz et al., 2012; Prokopy et al., 2008), there is a lack of variables which reliably predict how farmers accept and utilize climate and agronomic science to inform crop management strategies for climate risk adaptation. Previous research suggests that experiential/subjective knowledge and experimental/objective knowledge are differentially weighted as individuals consider decisions about the natural environment (Raedeke and Rikoon, 1997). Studies to understand decision-making among the farming population have largely taken an atemporal approach and have inadequately evaluated motivations for short- versus long-term farm management (Darnhofer et al., 2010; Riley, 2008; Reimer et al., 2014). Further, the role of an individual's time perspective, or the guide of current action differentially influenced by past experiences and perceptions of the future, is not well understood (Dietz et al., 2007; Raedeke and Rikoon, 1997; Anderson, 2013). As a result, there is currently a gap of scientific knowledge regarding the role of time perspective, particularly of past personally experienced events and intergenerational narratives about climate risks in farm management decision-making. A temporal reference framework representing past personal experiences and historical narratives is proposed to explore the influence of the past on current agricultural and land use management decisions associated with risks from weather extremes and climate variability.

## 2. Theory

### 2.1. Conceptualizing climate and time

The idea of analogs—something similar to or analogous to something else—is a useful heuristic to understand and conceptualize interactions between climate and time. Analogs act as benchmarks or reference points to which current and future climate risks are compared and assessed. For example, while considering the potential risks of a flood warning, one might recall personal past experiences and stories of others in similar situations to help inform personal vulnerability and the urgency (or not) to act in particular ways. In this case, if an individual has little or no experience or first-hand knowledge of flood risks, s/he may underestimate or substantively overestimate the extent of the risk. On the other hand, if flooding has been a common occurrence, the impact of past floods can be used as a benchmark for whether the current situation presents a greater or lesser risk comparatively. Thus, similar past events offer an analog to the present and influence perceptions of risk and available adaptation options.

Under global warming scenarios, the possibility of summers in Illinois to "feel like current summers in Texas or Oklahoma by the end of the century" is something that has not yet been experienced (USGCRP, 2009:117). However, there are benchmarks or historical analogs for similar types of environmental conditions and climate risks that can inform impacts and adaptive alternatives in response. For example, a multi-year, prolonged drought in the 1930s across the US Great Plains created an agricultural disaster of unprecedented magnitude. Prior conversion of prairie grasslands in a dry climate to cultivated row crops changed the seasonality of land surface vegetation coverage and resulted in the loss of perennial plant roots which held soil in place year around. Combined with drought and heat, this created conditions for wind erosion and extensive loss of top soil. The Dust Bowl, as it would come to be known, forced farmers to realize adjustments in common tillage and land use practices were needed. As the soil laden dust blew from the Midwestern fertile agricultural soils eastward towards the White House, Congress acted to establish the Soil Conservation Service in 1935 to address the management of soil and water resources under variable and extreme climate conditions.

Over time, however, new climate and weather analog events occurred, updating social knowledge of extreme weather impacts on agriculture. The drought and heat wave of 1988 that caused $40.2 billion in damages was a transformative event which created a new benchmark for drought events. In 2012, another historic Midwestern drought evoked memories of the late 1980s and Dust Bowl, becoming the new normal to which future climate risks of drought are compared. These experiences and narratives of drought risk are important for guiding current and future risk perceptions.

Perceptions of other agricultural climate risks, such as excessive water, are also evaluated and updated in reference to analogous transformative events. The "Great Flood" of 1927 displaced nearly one million people in the Mississippi River Basin and is regarded as transformative in shaping American's political, agricultural, and ecological landscape (Barry, 2007). Ten years later, the "Great Ohio and Mississippi River Flood of 1937" resulted from a prolonged period of early snow melt and high precipitation and covered more than 200,000 square miles with water depths above 11 in. (Welky, 2011). This "thousand year flood" was the benchmark event in the region until summer 1993 saw "unprecedentedly persistent" precipitation throughout the Mississippi River Basin (Kunkel et al., 1994). The flood of 1993 then became the new analog flood risk event to which current and future climate risks were assessed. In subsequent years, 2008–2010, the Ohio and Mississippi river valleys experienced a series of years with excessive precipitation and flood disasters to which personal memories and stories of the 1993 flood were compared (Olson et al., 2011). Then another "great" flood in 2011 occurred, breaching levees and flooding agricultural lands at the confluence of the Ohio and Mississippi rivers (Olson and Morton, 2012a,b). Farmers, landowners, and the US Army Corps of Engineers compared this flood to the 1927 flood to make sense of its magnitude and impacts. These examples illustrate how experiences and narratives of flood and drought and their outcomes are continuously updated as current events move backwards in time and become historical benchmarks for similar current events.

### 2.2. Building the conceptual framework

Perception of time and temporal horizons are influential in the creation of knowledge and subsequent decision-making (Hautala and Jauhiainen, 2014). Previous research finds that humans utilize a "temporal fulcrum" in the creation of knowledge to evaluate both historical outcomes and expectations for the future (Raedeke and Rikoon, 1997; Riley, 2008). According to Reimer et al. (2014), temporal scales are critical "in assessing the outcomes of individual conservation behaviors and long-term landscape interactions", but have not received much attention. We propose an expansion of the temporal fulcrum and construct a framework from which to examine farmer decision-making in the context of climate risks and agricultural management.

Our decision timescale framework elaborates a temporal model by utilizing the work of Jackson et al. (2010) and expanding the timescale to encompass the past. The Jackson et al. (2010) model frames decision-making in agricultural systems across multiple scales (spatial, temporal, and institutional) beginning at "now" and moving forward in time. Their scientific lens of conservation behavior and land use adaptive management focuses upon future-orientated behaviors and decisions. However, the influence of the past remains a gap in our knowledge about the relationship of the temporal scale to management decisions. There is a need to better understand human orientations to time, the role of past historical legacies and how the past is continuously referenced and contextualized as a feedback mechanism within the spatial dimensions of social-human-natural systems.

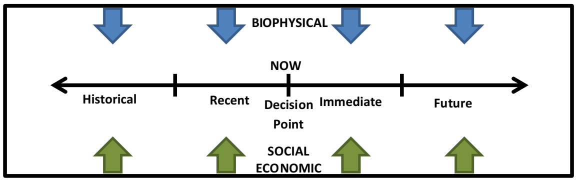


**Fig. 1.** Decision Timescale Framework. Decisions involve the consideration of multiple scales including temporal, spatial, biophysical, and social. This conceptual model posits decision-making as influenced by five time markers: historical and recent past events, current "now", and immediate and future outlooks.

The Decision Timescale Framework, Fig. 1, identifies five distinct time markers thought to influence decision-making: historical past (more than one generation ago), recent past (current ancestral generation), current "now", immediate future (current descendent generation), and distant future (future generations). Each of these time markers can be sources of social/economic and biophysical feedback which differentially amplify or attenuate perceptions of risk and subsequent adaptive decision-making (Pidgeon and Kasperson, 2002). These timescales are contextualized with a geographic scale that is influenced by extent or scope of individual observation (Atwell et al., 2009; Bourdieu, 1998). Immediate and long-term future perceptions of social and biophysical risks are conceptualized as individual perception of future climate risks and time perspective regarding impacts of current decision and actions. Historical and recent past social and biophysical experiences are defined as experience with environmental hazards and intergenerational narratives about hazards to farm enterprise and management decisions.

To fill the gap in the model proposed by Jackson et al. (2010), this research focuses on two distinct time markers: the historical and recent past. Historical past social/economic and biophysical experiences are defined as intergenerational narratives or stories that are passed through individual and family networks. Recent past social/economic and biophysical experiences are defined as those which have been personally experienced within the decision-makers lifetime.

Two distinct knowledge systems are activated in cognitive processing that result in decision-making and action. The first represents logical, rational, or analytical systems while the second represents emotional, affective, or experiential systems (Slovic et al., 2004). The analytic system is referenced by scientific knowledge that is learned through institutional channels. The experiential system is referenced by socially learned knowledge acquired through individual experience and interaction. These two distinct systems of cognitive processing parallel perceptions of temporal horizons: (1) Linear time is perceived as events having a logical and sequential order, while (2) relational or social time is perceived to be influenced by reference to social relationships and groups (Hautala and Jauhiainen, 2014). In other words, climate change-related behaviors, decisions, and actions may activate rational "reasoned and deliberative" responses and/or affective "habituation or automatic" responses (Fielding et al., 2014:415). Historical intergenerational narratives about climate and agricultural risks and past personally experienced climate and agricultural risks are not processed as linear time but activate the affective or experiential systems of risk perception. This affective system of risk perception can result in automatic or habituated decisions and actions in response to uncertain future risks.

The temporal reference framework posits that personally experienced past events and historical generational narratives have significant influence in affective risk perceptions that inform assessment and adaptive response to climate risks. Outcomes from past personal experiences and historical intergenerational narratives are used to inform current decision points. Previous outcomes that are analogous or similar in characteristic to current decisions affect how the event is weighted and processed as information used to guide decisions and behavior. Better understanding of the temporal reference can help scientists further explore the role of experiential processing, social knowledge, and socially-referenced time as it relates to the reception of climate science and applications to agricultural management.

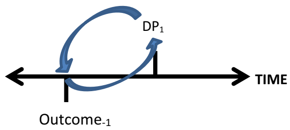


**Fig. 2.** Temporal Reference Model with basic feedback loop. Outcomes from past personal experiences and historical intergenerational narratives are used to inform current decision points (DP). Previous outcomes that are analogous or similar in characteristic to current decisions are given greater weight or importance when assessing potential decisions and action.

Fig. 2 illustrates the dynamic nature of the basic feedback loop process within the temporal reference model in which "now" decisions points (DP) are compared to past situations and decisions and their resulting outcomes. The temporal reference model hypothesizes an iterative relationship among past experiences and outcomes as decision points are assessed and acted upon over time. Time is conceptualized as a dynamic influence in decision-making in which multiple outcomes and experiences in the past, including personal experience and intergenerational narratives, inform a "now" decision.

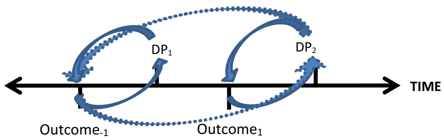


**Fig. 3.** Temporal Reference Model. Outcomes are given different weights based on perceptions and meanings assigned to the past and their impacts. In this model, decision-makers reference back to multiple timescales and outcomes, including both personally experienced events (depicted by solid lines) and intergenerational narratives of events (depicted by dotted lines).

Fig. 3 depicts the iterative and dynamic nature of the temporal reference model. In this model, decision-makers are posited to reference multiple past timescales, including past decisions made and outcomes. The solid lines indicate personally experienced events, while the dotted lines indicate intergenerational narratives about events. Analogous past outcomes and experiences are then synthesized by the decision-maker to guide perceptions of and decisions associated with current situations. Some events or experiences may be interpreted as transformative, which influence cognitive and emotional assessment of risk. As a result, the balance of risk and benefit in subsequent decisions may be skewed to favor specific outcomes and not others. In this model, decision-makers reference back to multiple timescales and outcomes, including both personally experienced events and intergenerational narratives of events. These past outcomes and experiences are synthesized to guide knowledge and perceptions of future outcomes.

### *2.3. Recent past personal experiences*

Recent past personal experiences are defined as events which occur within a human lifetime and are directly experienced by an actor or decision-maker. The theory of planned behavior, for example, highlights the principle of compatibility and suggests that the advantage of a behavior is perceived and assessed relative to past experiences of that behavior (Poliakoff and Webb, 2007:247; Ajzen, 1991, 2002; Ajzen and Fishbein, 1980). Past experienced events have consistently been found to influence perceptions of climate-related risks (Arbuckle et al., 2014, 2013a; Morton et al., 2015). For instance, in a study of California farmers, it was found that climate change attitudes are strongly predicted by past experiences with particular policies (Niles et al., 2013). Exploring soil conservation in Switzerland, Schneider et al. (2010:336) conclude that in "adopting no tillage, farmers have to fundamentally reconstruct their existing practices, experiences and concepts". Similarly, Thomas et al. (2007:892) reviewed 40 years of no-tillage farming in Queensland and concluded that "evidence of such advantages associated with no-tillage was generally anecdotal, based on farmer experience". This suggests that individual experiences act as analogs to which current decisions are compared.

Climate risks are perceived using a lens of influence which includes objective experiences of extreme weather and other social factors (Cutler, 2015). In the US upper Midwest, researchers found personal experience with excess water and saturated soils is significantly associated with use of drainage, tillage, cover crops, and planting on highly erodible land (Morton et al., 2015). Both analytical and experiential processing may be activated to codify experienced risks and cognitively decide to avoid or address them in the future (Slovic, 2000; Slovic et al., 2005). However, it has been suggested that risk perception may be amplified or attenuated by "social stations of amplification" (Renn et al., 1992; Pidgeon and Kasperson, 2002). After a transformative hazard event occurs, information of that event flows through social communities over time via news, conversation, and stories or narratives. In this case, social norms that impact descriptions and understanding of the hazard influence perceptions of the event characteristics, appropriate interpretation and behavioral response, and potential future impacts (Renn et al., 1992). Understanding social norms and symbolic narratives that influence risk perception over time can help connect risk perception to more quantifiable variables (Greiner et al., 2009). Of particular interest in rural agricultural contexts are the role of family structure and the transfer of stories pertaining to climate risks in the form of intergenerational narratives.

### *2.4. Intergenerational narratives*

Several factors influence how individuals and groups perceive climate risks and subsequently guide agricultural decision-making and actions (Arbuckle et al., 2015, 2014, 2013b). One factor that has received attention in agricultural management is the role of family and intergenerational values (Salamon, 1992; Salamon and Penas, 1986; Salamon et al., 1997). Family influences are important to understand because they impact a number of farm management practices in ways that are not well documented (Hildenbrand and Hennon, 2005). Further, the utility of a decision may include consideration of a resource's bequest value, or the value of preserving natural resources or cultural heritage (Fisher et al., 2009; Greenley et al., 1981; Frederick, 2006). Family history provides a blueprint for action and can influence "path dependence" to reinforce traditional decision processes that adhere to social norms (Inwood et al., 2013:363; McMillan Lequieu, 2015).

Family narratives about the farm's history, traditions, and trajectory into the future appear to have prominent influence in current decision processes. Narratives are often constructed and transferred in the form of stories, traditions, and culturally-reinforced mutual understandings which shape identity and normative behavior (Loseke, 2007). Historical narratives allow for current management decisions to be "grounded in the farm's history, past activities, and traditions" (Ingram et al., 2013:277). Intergenerational perceptions of land use and succession have been shown to conflict with economic incentives and conversion of land use to non-traditional crops (Neumann et al., 2007; McMillan Lequieu, 2015). For example, farmers with stronger family farm values are more resistant to converting farmland for alternative uses (Neumann et al., 2007). Symbolic meanings that reinforce traditional cultural practices and inform farmer knowledge can perpetuate normative action by sustaining fear of social disapproval or disgrace of family legacy (McMillan Lequieu, 2015).

In the Midwestern US, Salamon (1992) has contributed a large body of knowledge to the understanding of household level variables and the influence of intergenerational transfer of narratives in agricultural decision-making. Anthropological analysis of Yankee and German families in central Illinois during the 1980s provide evidence that family traditions and norms dictate management decisions concerning intergenerational succession to farming, land tenure, and adoption of sustainable farming systems (Salamon, 1993; Salamon and Penas, 1986; Salamon et al., 1997). It is suggested that family-level factors are important to farmer's perception of proper farm enterprise management, and that these factors may be sustained and perpetuated through intergenerational narratives about farm management (Salamon, 1992). Time perspective portrayed in these family narratives is also influential in land management. As Salamon (1993:582) explains, "how land is handled reflects what farmers consciously want to reproduce for the future and maintain from the past".

The role of intergenerational time perspectives in natural resource conservation is challenging for collective decision-making and policy development because there are many conflicting ways to consider decision timescales (Thompson, 2004; Boersema, 2001). Our research follows previous work presented by Field and Burch (1988) and applied by Salamon (1992) in conceptualizing time as a unit of analysis at the household level of a family life cycle. This allows for measurement regarding the role of intergenerational family narratives in developing perception of current and future risk and positioning farm management decisions within time frames or stations of influence. Time perspective may either reinforce or refute intergenerational "cultural legacy" or symbolic narratives that act as barriers or facilitators of agricultural adaptation (McMillan Lequieu, 2015:50).

Data from Midwestern US farmer interviews are used to test and refine the Temporal Reference Model (Fig. 3). Themes of time perception, social influence of decision-making, climate risks, and soil management are emphasized to discover how past personal experiences and historical intergenerational narratives are assessed to guide and influence current agricultural management practices. The concept of temporal reference is illustrated by providing empirical evidence from qualitative data and selected exemplary quotes from farmer interviews.

## 3. Methods

Data were gathered from in-person interviews with 159 farmers conducted in 2013 in the North Central Region of the United States. Geographic representation of interviews included Wisconsin, Indiana, Iowa, Minnesota, Michigan, Ohio, Illinois, South Dakota, and Illinois. Purposeful sampling of conservation-oriented farmers occurred through recruitment by land grant university extension educators. Participating farmers are large-scale commodity producers who grow corn and soybeans. Corn farmers with more than $100,000 in gross farm income in 2011 account for approximately 80% of the cultivated land in the region (Tyndall et al., 2015). Data from in-person interviews conducted in 2012 with twenty-two state and extension climatologists who engage with the agricultural population in the same region are also used in the analysis (see Wilke and Morton, 2015a,b).

Farmer interview prompts and questions were developed collectively by a team of social and economic scientists involved with the Climate and Corn-based Cropping Systems Coordinated Agriculture Project (CSCAP) project. Extension educators also provided input on question prompts and assisted in conducting interviews in their local regions. Interview protocol involved sections on conservation (emphasizing nutrient management, cover crops, and tillage), experience with weather variability, beliefs about climate change, sources of climate and agronomic information, and attitudes about agricultural sustainability.

This purposeful sample of farmers tends to be more conservation oriented, are often early adopters of conservation practices, and do not represent the entire continuum of Midwest corn farmers. A primary rationale for recruiting these farmers was to reach individuals who had some exposure and experience with key conservation practices (e.g., precision agriculture, no-till, cover crops) and who may have surmounted barriers or experienced challenges when adopting these practices. This sample of farmers may also have direct exposure to and experience with climate risk information and its usefulness and usability for farm management planning. Family members and farm partners were also invited to participate in the interview session if they desired. For a more complete and detailed description of methods, see Roesch-McNally (2016).

Interviews were transcribed, analyzed line-by-line and coded for major themes. NVivo qualitative analysis software assisted in coding and quantifying themes (NVivo, 2010). Development of a qualitative analysis code book guided analysis and assessment of concept frequencies to further refine and parse concepts (MacQueen et al., 1998; Miles et al., 2014). Conceptual themes that were analyzed include: (1) Time (historical and recent past, resent, future), (2) Social (family, friends, agency, informal and formal networks, social space), (3) Economic (crop prices, farm financial viability, crop insurance), (4) Geographic/spatial (farm field, watershed, nation), (5) Climate (precipitation, temperature), (6) Soil (water holding capacity, erosion, soil health), (7) Water (availability and quality), (8) Adaptive management responses (tiling, tillage, cover crop, crop rotations), and (9) Views of changes on the land (steady state, no change, dynamic, always changing). Two social scientists independently coded a subset of seven randomly selected transcripts to ensure inter-rater reliability. For each of the themes, Cohen's kappa reliability scores were greater than 0.825. The focus of this analysis examines the interaction among the themes of time, social, climate, and adaptive soil management.

## 4. Results

### 4.1. Time perspective

The weather and climate are on farmer's minds. Qualitative interview analysis reveals farmers connect climate and past weather events with the concept of time. While weather is a daily, short term experience, climate is the aggregation of average weather over time (NASA, 2005). Changes in climate may not be directly experienced in one human lifetime and are difficult to understand at human scales of perception (Dahlstrom, 2014). As a result, climatologists often face challenges in communicating the implications of climate science to agricultural audiences (Wilke and Morton, 2015a,b). Challenges of conveying the usefulness of climate science for agriculture may arise from a discrepancy in the time scales of how information is presented. For instance, while climate science is often conveyed in time scales of decades or centuries, agricultural stakeholders largely make cropping decisions annually and inter-annually (Takle et al., 2014). This temporal disconnect thus may inhibit the perceived usefulness of climate information and create challenges in climate science information.

Historical observations of climate were frequently perceived by the interviewed farmers to mirror future trends. This is articulated by a Missouri farmer, who comments, "The climate historically has always changed from the beginning of time, and I think it will always change as we trend forwards" (29037). He continues this thought with the observation that "I don't think that humanly we can control the climate". This theme was common across the interview transcripts. When asked about their opinions on climate change, more than 75% of the farmers responded with some reference to the past, historical events, or cyclical changes. This suggests that historical observations of weather and climate are used as a benchmark or analog to influence perceptions of future changes.

Another time theme throughout the transcripts involved the interplay of short- and long-term decisions. A Minnesota farmer discussed the time frame of agricultural decision-making as a much shorter time frame and suggested that farming sustainability and success were measured by whether "you're still around for next year to farm" (27007). A Missouri farmer elaborated on the time aspect of decisions: "I mean, if you look at a lot of farming operations, [they] are not short-term decisions" (29037). This farmer goes on to indicate that "our operation is probably five-, ten-year decisions...we've made a decision we're going to try and do something—it may be ten years before we get it done and over". These comments indicate that farmers are thinking about their decisions along a timescale which varies between individual farmers and certain decisions.

An Indiana farmer made a more specific reference to shorter timescales: "I can say I'm going to feed the world but, right now, I just want to put money in my pocket so I can pay my bills... That's a short range look, selfish look, but that's me" (18013). This suggests that while time is an important construct in which climate and agronomic decisions are referenced, multiple timescales may be considered by different farmers. The same farmer continued with an analogy that illustrates conflicts of crop and livestock growth time-scales. "I [have] got to be looking relatively short term, cash turnover, you know. Particularly on 75 acres. I'm renting that farm so the guy that I'm renting the farm from expects money every year. So I can't go out and plant walnut trees all over this and, you know, and try to raise squirrels for their hides". These remarks suggest discrepancies between annual timescales of crop production and multi-year scales of livestock production. The farmer is making a joke about the inability to make long-term management plans because of the economic realities of annual crop land rental.

### 4.2. Recent past personal experiences

The role of past personal experience is another prominent theme that was evident throughout the transcripts. For instance, an Iowa farmer remarked, "This year, we're plenty cool so I can't say that we're into global warming because we've experienced enough cool years in the last 5 years also" (30101). This experience of cool years leads the farmer to continue with the conclusion, "I'm not a big believer in the global warming thing and climate change". A Michigan farmer illustrated how experiences with yield mapping influence nitrogen management decisions. "We've had yield mapping here since 1995...so we can look at trends and things like that and put realistic goals in for nitrogen" (26024). A farmer from South

Dakota described how the drought impacted tillage management: "After the drought of 2012...maybe we should do something different. Maybe we should quit running machinery, burning fuel, you know, over these fields. Maybe blacker [soil] isn't always better" (46012). Experiences of climate and agricultural management risks are often depicted as rational for decision-making, as this Minnesota farmer describes:

> "We'd go till the ground, whether it was a plow or chisel plow or what have you, and the creek would come out and flood and we saw that we were losing significant amounts of soil. So what we decided to do was, we didn't take any government program, there was no program of any kind, we just decided that we're going to seed this down into grass."
>
> [(27012)]

Personal experiences with soil management are also perceived and acted upon by different generations. The following observation from another Minnesota farmer illustrates how previous generations can act as gate keepers to reinforce a "cultural legacy" or status quo of soil management decisions.

> "My dad was adamant we had to do some tillage. And one year we had ... on his farm has kind of a small hill that's kind of light ground and I thought, well, if I work this, it's going to blow in the spring. And when I was drilling it, of course, it's kind of rough... Where we hit that spot, it was so nice and smooth; it was like driving down a highway. And I got out and kicked in the dirt and it's nice and soft and mellow. You walk back where that heavy disk went, it was clotty; it was hard. And I, actually, had him [dad] drive out to the field. I said, come here and look at this. And we were walking back where I had drilled and we was on this hilltop and he said, don't go so fast, I'm twisting my ankle. And I said, exactly, that ground's hard as a rock... You walk back here and you're kicking the dirt and nice and mellow. He said, yeah, just do what you want, and he left. So that's when we switched completely to no-till."
>
> [(27007)]

Regional comparisons of agricultural production in relation to experiences of extreme weather events also signaled changes in soil management. This Illinois farmer describes how they adopted no-till after more than 20 years of conventional tillage after the droughts of the late-1980s.

> "We continued with the conventional tillage until 1989. '88 was, of course, the nationwide drought year. '89 here was even a worse localized drought year. So we decided to take a real serious look at the way we were doing business because there was a fellow that was doing no-till right next to us and he'd already been in the process 10 years and it was, basically, in its infancy then, you know. There wasn't a lot known about it but he was killing us on yields, probably doing 30–40 bushel better than we were."
>
> [(17005)]

Reports of recent past personal experiences often reflect what climate scientists have been predicting. For instance, recent reports indicate that extreme precipitation events (defined at 2–4 in. per day) are becoming more frequent in the Corn Belt region (Arritt, 2016). A Wisconsin farmer reports that "...it seems our rains are less frequent, they're heavier, they're more intense than they were, than I ever remember" (55021). This farmer continues by observing that "...when we get a rain now, it's a couple inches at a time or it's just a trace". The Wisconsin farmer in this case is reporting personal observations that are congruent with climate science predictions for the region.

### *4.3. Intergenerational narratives*

The concept of sustainability is linked to timescales which encompass multiple generations. A commonly used definition describes sustainable actions as those "which meet the needs of current generations without compromising the ability of future generations to meet their own needs" (United Nations, 1987). Therefore, stories or narratives passed down through generations to depict historical events, traditions, and norms are important to understanding the relationship between time perspective, climate, and sustainability of the farm.

Mentions of relics and symbols of the past that were referenced to assess perceptions of current and future changes are evident throughout the farmer interviews. For instance, an Indiana farmer responded to a question of changes in climate by remarking, "I'm not sure how much things are actually changing. I wish I had a dinosaur around to ask him, you know, what kind of changes I should be looking at" (18013). Reference to the historical past is also evident in farmers' understanding of inter-annual weather variability. "They have like average temperatures, average weather and there is no such thing... It's an average of the extremes, you know. Like we come off such a dry year and now we're wet. I think that's just probably the way it's been a long time" (30101).

The theme of intergenerational narratives is conceptualized by references to the historical past in relation to generational or family contexts that influence decision-making. This concept is exemplified by the following remark from an Indiana farmer (18013): "Who in the hell is not trying to sustain a living? And sustain the farm? So, why, all of a sudden, is this [sustainability] a new concept? Do you think my grandfather, my great-grandfather; my great-great-grandfather didn't try to sustain a living? So this term, as you can tell, seems completely worthless to me. So that is my answer to sustainable agriculture". A Michigan farmer remarked about the pressure imposed from previous generations: "It's tough to buck tradition...this is how we do it, this is how grandpa did it...there's peer pressure" (26028). Another farmer described generational resistance to changes in agricultural management: "It was a big change to think about doing it that way, you know, because dad and grandpa hadn't ever farmed that way" (27008).

Another Indiana farmer elaborated on the importance of family members and intergenerational transfer of environmental perceptions that are brought forward in relation to time: "We all learn from our peers, whether it our mothers and fathers or our aunts and uncles or whatever. So sustainability's something that you want to pass on to your blessings, so to speak" (18018). A Minnesota farmer exemplifies how long-term agricultural sustainability may be thought of as continuing the operation as it is today. "I would say a long-term sustainability, to me, as a fifth generation producer, would be a steward of the land, to continue the farming operation as we know it today" (27010). This same farmer continued to remark, "It's something that you take a lot of pride in, as the fifth generation. You assume some of the things, prior to, were done right otherwise you wouldn't be here talking today so you kind of want to carry on some of that tradition, as well" (27010).

The theme of intergenerational farm continuation of pulling the past forward in time was directly described by many farmers throughout the region. A farmer in Michigan said, "In all honesty and morality, we need to be careful and preserve it for next generations and leave our legacy behind" (26027). "Long-term sustainability," another Michigan farmer remarked, "is maintaining the farm and trying to improve the farm so that generations that come after me still have something to work with" (26004). An Ohio farmer declared, "The farm gets passed down from generation to generation in as good or better condition than you receive it" (39012). "I guess sustainability means that I'm doing things in a way that keeps my farm efficient and productive and gives me the ability to continue doing what I do," says a Minnesota farmer, "continue doing what *we* do, hopefully, for the next generation, generation after that" (27021).

Some farmers suggest they perceive the sustainability of their decisions to resonate through long-term time frames that may be more congruent with climate timescales. For instance, one Michigan farmer remarked, "We got to think down the road more than my lifetime to make sure the environment's going to be—or have the ability—to grow crops and keep the next generation going" (26005). The farmer concludes this thought with, "I mean, long term's not a year—it's not my lifetime". One Missouri farmer provided a similar thought: "I guess the long-term goal is sustainability and how can we improve the tilth of the soils and the environment, and the livestock operation, to where it has the long-term benefits not only for this generation but generations to follow" (29037). Livestock production is often a multi-year operation and may allow farmers to consider agricultural decisions beyond annual timescales.

## 5. Discussion

The concept of sustainability in agriculture is grounded in time with past actions influencing current conditions and future possibilities. Farmers in our sample viewed sustainability as bringing the past forward into the future. The data provide evidence that sustainability, climate, and agricultural risks are assessed through a lens of affective response formed by past personal experiences and historical intergenerational narratives. These experiences and historical events construct local knowledge and build social learning. This knowledge acts as a filter through which scientific experimental/objective knowledge is perceived and evaluated for its usefulness and usability in agricultural decision-making.

These farmer interviews offer strong support that the past is intimately connected to the present and future and often used to guide current decisions about the farm enterprise. Further, farmers do seem to delineate the recent past from the historical past, suggesting that the temporal reference model provides a good starting framework from which to identity key variables that represent the past. The iterative nature of incorporating past events, past decisions and resulting outcomes as information for a "now" decision is particularly apparent in farmer discussions about sustainability and long-term goals for their farms. What is not clear from these interviews is how recent past and historical narratives differentially influence current decisions. Future research might consider the differential impacts of transformative events (such as extreme weather) or incremental events (such as gradual changes in climate over time). For instance, does the past experience have to be a huge event, a disaster, or remarkable success to be recalled and given substantial weight to be incorporated into the decision? Further, how might patterns of the past be utilized to improve adaptive management responses to a changing and highly variable climate? This also raises questions for future research, such as the appropriateness of assuming that past agricultural experiences may be useful to inform current and future climate risk.

Jackson et al. (2010:80) suggest that "maintenance of future options requires preparation for uncertainty, and for quick and agile adaptation, given the rapid pace of change... This is in contrast," they continue, "to simply sustaining the present conditions". Our data suggest that Midwestern corn farmers largely perceive adaptation to climate risks for agricultural sustainability as bringing the past forward. This may inhibit "quick and agile adaptation" and disrupt the adaptive flexibility required to maintain resilient systems facing uncertain future climate risks. It is necessary, therefore, to consider how current management decisions are iteratively always moving to being the "past" and informing future "nows". This suggests that the past not only informs the current here and now, but influences the pathways of future decisions and outcomes. Giving preference to past experiences may privilege "path dependence" along the current trajectory and limit adaptive capacity for response to future uncertainty and change (Inwood et al., 2013:363). Better understanding of how individuals privilege past experiences and historical narratives can help us reorient our interventions and personal awareness and improve how agricultural climate risks are addressed.

Many conservation practices, such as reduced tillage and cover cropping, produce agronomic and environmental benefits that are compounding over time (Lal, 1993, 2004; Grandy et al., 2006). In other words, benefits of these management practices may not be realized within annual time cycles; rather, benefits accrue in longer-term time horizons. As a result, it may be challenging for a farmer or land manager to balance risks and benefits of farm enterprise economics, soil health, and carbon sequestration or increases in soil organic carbon.

Regional case studies that document peer farmer success over time may be helpful in communicating effects which are compounding over time. These case studies should include both current and past yield data, changes in soil organic carbon loss/gain, and water monitoring for nitrogen and phosphorous levels over time so that farmers can directly compare and create their own analogs from their personal past experience. Performance-based management processes track these kind of data and use past management and outcomes as benchmarks from which to make future management decisions (Morton, 2008). By viewing soil data in relation to other fields within the watershed, for example, farmers may be more inclined to shift their soil management techniques. Measuring, monitoring, and evaluation of past field, farm, and watershed level activities by farmers involved in performance-based management watershed groups have been shown to change beliefs and knowledge of farmers as well as their practices (Morton, 2008).

During the historical drought year of 2012 in the Midwest Corn Belt, many no-till corn crops produced greater yield than crops in a continuous tillage system (Kumar et al., 2014). Viewing the agronomic data of peer farmers using conservation management techniques may allow farmers to develop analogous cognitive representations of their own management decisions in relation to their personally experienced climate risks, environmental conditions, and agronomic outcomes. By making comparisons to other regionally-relevant operations, farmers may better understand how certain management techniques, such as no-till, have performed over time and in different weather and climate conditions.

## 6. Conclusion

Agriculture is a complex human-natural system with intricate and continuous feedback loops. Like all humans, farmers learn from the past. Intergenerational narratives and experiences with recent past extreme weather events and variable climate patterns often become analog years used as benchmarks to build knowledge of the natural environment and guide decisions. This social learning process combines synthesized knowledge from the past, values, and new factual information that impacts outcomes for the farm enterprise and the dynamic relationship it has with the agroecosystem. Famers have different histories and these histories uniquely inform the values, beliefs, risk perceptions, and confidence they bring to decisions large and small on their farming operation (Arbuckle et al., 2014). The challenge ahead is to help farmers successfully adapt to changing climate conditions and changes in the agroecosystem. Ensuring sustainability at the farm and landscape levels under a variable climate means accomplishing multiple objectives: livelihood, co-production of good yields and preservation of soil, water resources and other ecosystem services needed in the "now" and in the future.

Climatologists in the North Central Region are an important bridge between climate risk information and agricultural data users. Many climatologists have important insights and understand the challenges and barriers to effectively communicating climate risk (Wilke and Morton, 2015a). The temporal reference concept has been articulated well by one climatologist who remarked that analog years were useful in talking with farmers: "... if a producer says, 'You know, I really remember summer of 2005—it was really wet.' I think what happened in the past and what that person did has a big influence. Kind of their own personal history with farming and what they remember the weather like" (703).

This suggests that highlighting personally experienced and regionally-relevant information can help influence perceptions of the usefulness and usability of available climate information. Matthews et al. (2016:37) explore how to bridge climate science with wider society and conclude that "framing future climate scenarios in the context of extremes from living memory will help communicate the scale of the challenge climate change presents". Haigh et al. (2015) similarly suggest that historical climate information may assist in quantifying potential uncertain climate risks for agriculture stakeholders. Advances in climate scenarios, such as those described in the Third National Climate Assessment, may benefit from incorporating historical climate analogs (Moss et al., 2010; Melillo et al., 2014). The climatologist above continued to expand on the use of historical analogs which resonate with farmer memories:

> "I think as climatologists our knowledge of possibilities in the future and uncertainties and helping to identify risk—that's probably a good use of our knowledge. Maybe even using analog years. Say in the future it might be more like the heat and dryness of the 1930s, for example. Maybe not that extreme, but trying to find ways to use, say, the historical climate or things that people can remember or put into context as a guide for the future. I think that's one way that we can help". [(703)]

Qualitative analysis of farmer interviews provides preliminary support for the temporal reference framework. However, limitations in the generalizability of this sample suggest more empirical testing is necessary to further validate the model. Interviews should be conducted with other agricultural stakeholders—including certified crop advisors, input dealers, agricultural scientists, and extensions educators—to assess their perspectives of time in relation to climate and agriculture. Further, survey questions should be developed and validated to quantify the time range of historical influence for decisions relevant to climate and agriculture. This will allow scientists to further parse out the specific time frames and contributions of recent past experiences and historical narratives. Content analysis of historical documents can also provide insight into how transformative extreme weather events, such as drought and floods, impact regional changes in agricultural management techniques.

These findings have practical application for climate and agronomic scientists and other stakeholders who bridge climate science information and agricultural decision-making. A recent U2U-CSCAP report, "Climate Change and Agricultural Extension: Building capacity for land grant extension services to address the agricultural impacts of climate change and the adaptive management needs of agricultural stakeholders," suggests the need to "Talk about trends over time" (Morton et al., 2015). By doing so, climate risk communication efforts should not only rely on future-oriented or foresighted strategies, but rather incorporate a time range that includes temporal reference to historical events and past experiences. For instance, are climate risks becoming more extreme relative to the past? This may allow farmers to accept and utilize information about the compounding effects of soil management decisions over time, for example, to develop effective climate risk management strategies that ensure productivity and resilience of agricultural landscapes well into the future. By connecting climate science to agricultural traditions, we may better manage landscapes of the future.

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